IMPERIAL BUREAU OF ANIMAL NUTRITION

Technical Communication No. 1

A.I.V. Silage

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A.I.V. SILAGE.

In the conservation of the luxuriant summer production of green fodder for use as winter food for live-stock, one of the most important considerations is that the process should ensure the maximum retention of the original nutritive qualities of the material preserved. Hay made under ideal weather conditions is an excellent food, but the unreliable climate and comparatively high rainfall of Northern European countries render it impossible to preserve grass in this way without impairing the original nutritive and vitamin content. This may reduce its value by as much as 50 per cent. Consequently investigation has been made into alternative methods, the most economical of which have been the preservation of grass in the form of silage. Numerous and sufficiently well-known variants of this principle are practised; but most of them involve a certain loss in the nutritive value of the original material.

In a country like Finland, where the summers are short, the provision of adequate supplies of nutritious winter food is of prime importance. In 1925 Dr. Artturi I. Virtanen, Director of the Research Laboratory of Valio, the large Finnish Co-operative Dairy Organisation, began an investigation into the preservation of grass in the form of silage, and he has now devised a technique by which he claims a conservation without fermentation and with all but an insignificant loss. To this process the name of A.I.V. silage has been given, derived from the initials of the inventor. As the relative literature is scattered, and mostly in the Finnish language, the purpose of this note is to summarise, for the benefit of numerous enquirers, the existing information on the process.

Theoretical Basis of Method.

Virtanen started from the assumption that the conservation of green forage without noticeable loss is possible only when the splitting up of the nitrogenous material in the green forage by proteolytic enzymes is completely prevented. He had already observed that

neither in the cells of higher plants nor in bacterial organisms themselves did there occur proteolytic enzymes capable of acting at a *p*H index lower than 4. If, therefore, the degree of acidity in the green fodder is brought down below *p*H 4 in the conserving process, the breaking down of the nitrogeneous substances is prevented. In laboratory experiments it was shown that acids such as hydrochloric acid, sulphuric acid, phosphoric acid, lactic acid, etc., could be homogeneously mixed with the fodder and that by this means the *p*H value of the mass could be kept below 4 when once it had been reduced to that figure. Since much larger quantities of weak organic acids than of strong mineral acids are required to obtain the same *p*H index, it became apparent that in practice the principal mineral acids would be most suitable. Laboratory trials proved that food preserved with hydrochloric acid was highly satisfactory from the bacteriological point of view in that no development of coli and butyric acid bacteria took place.

It is the attainment of the correct *p*H value by the addition of acid which constitutes the essential feature of the method. Though it is generally accepted that hydrochloric acid is the acid which plays the chief part in the process, practical considerations have led to the use of a mixture of acids the exact composition of which is not known. This solution is termed the A.I.V. solution. The next step was to subject the method to practical tests on the basis of the laboratory experiments.

Application of the Method in Practice.

The standard type of A.I.V. silo is circular in shape, 16½ feet in diameter and 5 feet deep. A smaller type, 3 metres in diameter, is recommended on farms having less than 15 milk cows. The pit is dug somewhat wider than 5 metres to facilitate the construction of the cylindrical wall of planks, after which any empty space outside the wall is filled in with earth and stamped down. Sites, free from sub-soil water, on rising ground near the farmyard or crop to be ensiled, are generally selected. The bottom of the silo pit is levelled, and, where the soil is clayey, spread with a layer of clean gravel. No floor boards are used. Where possible a drain pipe should be laid from the centre in order to carry off the sour liquid which collects after the pit has been filled. If, owing to the presence of sub-soil water, the pit cannot be made deep enough, the walls may project above the ground, in which case earth must be banked up outside and covered with sods.

If necessary, the silo can be erected entirely above ground and the wall of earth and sods piled up correspondingly high.

When finished, the pit is filled with fresh fodder (chopping up is unnecessary) spread as evenly as possible in lots of about 450 lbs. at a time, and sprinkled with the A.I.V. liquid, which is measured out accurately in accordance with the directions supplied. This solution is poured from watering cans which have been previously coated inside with varnish or rubber. Each successive lot of 450 lbs. is tramped down as evenly as possible, rubber boots being worn in preference to leather, as the liquid gradually destroys the latter. When the pit is quite full, a closely-fitting circular upper section, constructed of planks 6½ feet long, is placed in position, and the filling-up proceeds as before until this upper section is also full to the brim. Clean boards are then placed on top in the form of a lid, which is then weighted down with heavy stones or sandbags. The whole is left to settle for one night, after which the weights and boards are removed, and the silo once again filled to the brim. The top layer of fodder, especially near the edges of the silo, is sprinkled with a fluid called " Mildew-death " which prevents the formation of mould. The silo is now ready to be covered in.

In covering, the object is to press down the material in the section above ground until its upper surface is level with the edge of the pit. Experience has shown that if the foregoing measurements and instructions are observed, this will be achieved by the pressure of a layer of clay 1½ feet deep. The procedure is as follows : Over the green mass a layer of newspapers is first spread followed by a layer of wet sawdust or peat mould 4 inches thick. In autumn the latter may be replaced by beet leaves, in which case newspapers are not necessary. On the top of the sawdust (or beet leaves) is placed a layer of earth 20 inches deep, which is well trodden down and smoothed over. In the course of three days the green mass will have sunk down level with the top of the pit. The upper section, which is now empty except for the layer of earth, is removed—a matter of no difficulty, as it is constructed of six or eight separate pieces which are easily erected and dismantled. Its final form is that of a flattish cone so that rain water will easily run off. Finally it is covered with straw held down with planks or brushwood, which serves as a protection against extremes of weather. The pit remains thus until its contents are needed.

Concrete towers may also be used. These are usually 25 feet high by 16½ feet in diameter and have a hole in the side through which the

food is removed. The method of filling is the same as for the pits, but no newspapers, sawdust or earth need be employed as covering materials. The top is covered with a wooden cover on which stones to the weight of 500 to 600 lbs. per 10 square feet are placed, and the silo is roofed over when full. Concrete silos are usually built close to farm buildings, while the pits are generally dug in the fields at appropriate points, the food being carted in when required.

The food is ready after the lapse of about two months, and practically no loss of nutritive value is found to have taken place. Certain factors may, of course, cause failure. Water collecting at the bottom of the pit may injure the silage in varying degrees, in some cases entirely spoiling it. If the mass is not sufficiently tramped down, or if too little earth is spread on the top of the finished silo, air may penetrate, thus giving rise to the formation of moulds which cause protein break down and alteration of the *p*H index. Material which is not quite fresh at filling may also cause mould-formation. The correct addition of the A.I.V. liquid is another source of trouble, but with care and precision the preparation of the silage is reported to be easy and satisfactory. The silage should be removed from the pits in layers and not in blocks, and each time food is removed the pit should be recovered with sacking and straw as a protection against frost.

The A.I.V. Liquid, and the Solution known as "Mildew-death."

The liquid supplied by the Valio Laboratory is diluted before use. One and three-quarter pints of liquid is added to five and a quarter pints of water. The quantity to be applied is varied according to the character of the green forage employed. It is stated that the quantities used for 200 lbs. of green forage are the following :—

For clover and other leguminous crops . .	12 lbs.
For grasses	10 ,,
For clover-grass mixtures	11 ,,
For kale and root-crop leaves	8 ,,

The quantities are for material of normal moisture content, but it is recommended that they be increased by 1 lb. per 200 lbs. of green material if the weather is very dry when the crops are being carted. The composition of the acid solution to be added to the forage presents no scientific secret, for, according to Virtanen, it is a matter of complete indifference what kind of acid innocuous to animals is used. It was only practical reasons which led Virtanen to use an

acid mixture in which the principal constituent is hydrochloric acid. To achieve success it is absolutely necessary to ensure that a definite quantity of this chemical solution comes in contact with a definite quantity of the forage to be preserved. Any alteration in the prescribed amounts will not give the desired result.

Close attention must be given to the prevention of the growth of moulds which form one of the chief causes of failure. This is most liable to occur in the top layers of the ensiled mass where the access of air is easiest. In the search for a specific against mould, Virtanen proceeded from the observation that A.I.V. feeds prepared from cabbage tops do not as a rule become mouldy even when the silo pit was imperfectly covered and admitted a certain amount of air. From this he inferred that crucifers contain a substance toxic to mildew. This assumption proved to be correct inasmuch as the mustard oil found in the cruciferæ was very effective against mould even in high dilution. Using a solution containing 0·001 per cent. of allyl mustard oil no moulds occurred. This substance Virtanen has named " homesurma " or " mildew-death," and in a pit or elevator 16½ feet in diameter one-third of an ounce of " homesurma " is sufficient to protect the surface of the feed. Tests, undertaken to ascertain whether " homesurma " was harmful to animals, showed that high amounts fed to a cow daily for two weeks produced no ill effects.

Choice of Raw Material for Ensilage.

Attention has been given by the users of the process to the type of raw material which is most suited to this method of ensilage and what green crop is economically the most advisable to cultivate.

One must choose plants which have a luxuriant foliage and yield heavy crops, and the green material must be sufficiently juicy so as to facilitate pressure into compact masses. Leguminous crops, which naturally have a high nitrogen content, are the most important. Feeding peas and vetches are of this nature, but suffer from the disadvantage that they are weak in the stem and hence are usually sown with some supporting crop such as oats or other cereal. These latter, however, are not entirely suitable for A.I.V. fodder, owing to their encouraging the formation of mould during the process of conservation. In Great Britain and Central Europe, the horse-bean (*Vicia Faba* L.) has been found to provide a satisfactory support to vetches and peas, and an excellent A.I.V. fodder which is readily eaten both by horses and

cows is obtained therefrom. Pastures in which clover thrives come next in importance. Cuts should be made as early as possible, preferably just before the clover flower-bud is formed. Flowering Timothy grass is not recommended as a basis for A.I.V. feed. In Finland the cultivation of rye crops for silage appears to be gaining favour. Many other green crops have been used, among which kale has been found very advantageous. The lower portions of the kale stem to a height of some 4 inches are quite valueless for food, however ; therefore kale should be harvested by a machine and not pulled up by the roots.

Characteristics. Composition. Practical Feeding Tests.

A.I.V. fodder is readily consumed by animals. When ready it is rather moist and has a sweet and slightly acid taste. The odour is agreeable and it is stated that cattle will take it in preference to turnips if offered a choice. Analyses of numerous samples of A.I.V. feed have been made and it is claimed that food preserved in this way does not suffer any material loss of nutritive value. The accompanying table, compiled from Virtanen's own data, shows a comparison between the protein content of fresh Timothy grass and that of A.I.V. silage prepared from Timothy grass :—

Table I.

	Fresh Timothy Grass. (Av. 6 samples.)	A.I.V. Silage from	
		Timothy Grass. (Av. 12 samples.)	Clover Aftermath. (Av. 3 samples.)
% Dry matter	21·8	21·0	23·6
% Crude protein in dry matter .	14·8	14·6	17·2
True protein { % in crude protein .	84·3	82·5	88·0
	12·4	12·0	15·1
Soluble albumen { % in true protein .	50·3	50·5	69·0
	6·2	6·0	10·4

According to these figures the true protein of fresh Timothy grass amounts to 84 per cent. of the crude protein. In the A.I.V. Timothy fodder the corresponding figure is 82·5, thus showing that little decomposition of protein substance takes place in the A.I.V. treatment. The proportion of soluble albumen in the true protein is the same for the fresh as for the ensiled grass, namely 50 per cent. In A.I.V.

feed prepared from clover, the true protein averages 88 per cent. of the crude protein and the soluble albumen 69 per cent. of the true protein. Though corresponding figures for fresh clover are not quoted in the literature, these values are, according to Virtanen, the same as are found for fresh clover. It must be noted that from the published analytical data, it is not clear whether the analysis of fresh Timothy grass was made on samples from the same crop as was ensiled and subsequently analysed after treatment, or whether the fresh grass figures refer to some different crop from that ensiled.

In feeding experiments it has been possible by using A.I.V. to the extent of 50-60 per cent. of the food required, to reduce the usual amount of oilcake by one-half and still maintain an unchanged milk yield. Even more advantageous results can be obtained by using the feed at the rate of 70-90 per cent. of the total food, particularly if silage prepared from clover or clover-rich grass is used. In Table II, the yield of four groups of cows at the same stage of lactation and on A.I.V. feeding is compared with four similar groups on ordinary feeding :—

TABLE II.

	A.I.V. Silage Groups.			Hay-Turnip Groups.		
	Food Consumed.		Milk Yield.	Food Consumed.		Milk Yield.
	Oatmeal.	Oilcake.		Oatmeal and Bran.	Oilcake.	
	Kg.	Kg.	Kg.	Kg.	Kg.	Kg.
Group I (4 cows)	400·3	266·9	4837·3	712·5	970·1	4707·3
,, II (2 cows)	147·8	165·2	1955·0	385·0	429·0	1884·2
,, III (2 cows)	203·7	203·7	2664·0	460·0	247·0	2412·0
,, IV (2 cows)	232·6	232·5	2860·2	362·6	362·6	2496·1
Total	984·4	868·3	12,316·5	1920·1	2008·7	11,499·6

In the A.I.V.-fed groups there has thus been an increased milk yield of about 7 per cent. Furthermore, this has been achieved by the use of 56 per cent. less oilcake and 48 per cent. less oatmeal (and bran) than in the normal groups.

In general, it appears that about 90 lbs. A.I.V. fodder is considered the normal daily ration for milk cows of average yield. No digestive disturbances have been observed. A few examples of the results

of feeding tests made on holdings where the live-stock dietary was based on A.I.V. fodder are given below :—

(*a*) *Anola Estate :* 200 cows fed a daily ration of 90 lbs. A.I.V. silage (Timothy and clover), 5 lbs. concentrates (oatmeal and soya bean meal), 5½ lbs. hay (inferior quality), and 9 lbs. oat straw, gave an average milk yield of 36 lbs. per day.

(*b*) *Pätiälä Estate :* 25 cows fed a daily ration of 90 lbs. A.I.V. silage, 5½ lbs. hay, 13 lbs. skim milk, and 9 lbs. oat straw, gave an average milk yield of 36 lbs. per day.

(*c*) An Ayrshire cow fed for 43 days before calving with 70 lbs. A.I.V. silage, 3½ lbs. straw, and 6½ lbs. hay, gave after calving an average of 35 lbs. milk per day for 51 days on an average ration of 6½ lbs. hay and 84 lbs. A.I.V. silage, with no concentrates. The yield progressively increased from 32 lbs. at the beginning to 44 lbs. per day at the end of the period.

(*d*) A cow fed all the year round with about 5½ lbs. hay and 90 lbs. A.I.V. silage per day, together with pasturage for three months in the summer, and no concentrates whatever, gave a milk yield of 900 gallons during one lactation period.

Cost.

The cost per food unit of preparing A.I.V. silage is reported to be about equal to or rather less than the cost of hay making. In one case the cost of preparing 640 tons worked out at 3·1 man-hours and 3·5 horse-hours per ton of fodder. Calculated from Finnish currency at par rate of exchange the equivalent working cost in sterling is about one-fifth of a penny per food unit. To this must be added the cost of growing the green crop and the cost of constructing the silo, which brings the total cost in the byre to about three farthings per food unit. The cost of building concrete towers and pit silos is relatively small, being for the former about £70, and for the latter about £5. These are the equivalent par sterling values of costs given in Finnish currency.

Costings made on one farm showed that, by using A.I.V. fodder, the cost of butter-fat production was reduced by 30 per cent.

Effects on Animals and Animal Products.

Fears have been entertained that A.I.V. fodder may react unfavourably on the metabolism of lime and phosphorus. Those qualified to speak, however, state that there are no grounds for this supposition, as after intensive tests of three years' duration no disturbance of mineral metabolism was noted. The ash of this fodder has a basic reaction, but one can further safeguard against acidity by adding a neutralising salt. In fact, Virtanen recommends that chalk and sodium carbonate should always be given along with A.I.V. To 60 lbs. of the feed 2 ounces of chalk and 1 ounce of sodium carbonate is sufficient.

Large scale tests by the Valio concern show that the state of health of cows fed on A.I.V. feed was particularly good. In some few cases, where the fodder used had been very much cooled down, it caused chills and digestive disturbances.

The milk from cows fed on A.I.V. silage is said not to have the peculiar taste which occasionally results from the use of other types of pressed fodder, and many users of ordinary silage have changed over to the A.I.V. product for this reason. Butter has the rich yellow colour of summer butter, indicating that nothing is lost by this new method of preparing fodder. The consistency of the fat is the same in winter as in summer, whilst the crumbly texture, typical of winter butter, is eliminated. The only cheese that cannot be made from the milk of A.I.V. fed cows is Emmenthaler, and researches are in progress to determine why this should be so. On the other hand, the milk is well adapted for the more acid cheeses, such as Edamer, etc.

Extent Practised. Patents.

Thanks to the enterprise of the Valio Co-operative Dairy concern, the method has been intensively developed in Finland and is apparently in widespread use in that country. The results obtained are so good that some 70,000 tons of A.I.V. ensilage were prepared in Finland in 1930. The measures adopted by Valio to promote interest in the process consist of lectures, advisory work, field demonstration, etc., and in all, 12,000 persons received instruction in the preparation of A.I.V. fodder during 1930. Instructional tours were extended to countries outside Finland and the claims made for the process are being investigated in Denmark, Sweden, and Germany. A certain amount of criticism of the process has been

forthcoming from these countries of which mention must be made. One aspect of this has been to ascertain the import of Finnish claims to patent rights. The basic principle in the new method of conservation has been protected in the most important cattle-rearing countries by a patent applied for in the name of Virtanen and the Valio Co-operative Export Association. It appears that some objection has been made to the granting of patent rights on the grounds that the principle on which the method is based is not new. Virtanen admits that patent protection is not usually sought for discoveries relating to agricultural method, but takes the standpoint that possession of a patent gives impetus to the new enterprise. It stimulates the investment of money and facilitates the promotion of advisory propaganda. If, for example, anyone in Finland were free to sell acids for the preparation of A.I.V. fodder, no effective instructional work could be carried on in the face of competition, and the method would certainly fall into disrepute owing to faulty application.

Interest in Method in Sweden, Denmark, and Germany.

In the latter part of 1931 considerable discussion took place in the columns of the Swedish agricultural press regarding the application of the Finnish A.I.V. method in Sweden. Controversy between Swedish agricultural authorities and Dr. Virtanen centred round the validity of the Finnish patent claims, it being pointed out that priority in the discovery of the use of hydrochloric acid for regulating the action of proteolytic enzymes belongs to Germany and not to Finland. Attempts to circumvent the patent were made by making slight alterations in the A.I.V. technique, and extensive investigations were carried out by Swedish agricultural authorities on a method described as "similar" in the main to the Finnish method. The essential difference in the Swedish method lay in the composition of the preservative solution which consisted of molasses mixed with a small amount of hydrochloric acid and a little sulphuric acid. The amount of acid added is insufficient to stop fermentive processes, and the object of adding molasses is to hasten the formation of lactic acid which otherwise takes place gradually at the expense of the plant carbohydrate stores. This procedure is different from the A.I.V. method and it is thereby asserted that the patent claims of Virtanen are not transgressed. Virtanen eliminates enzyme action and makes an unfermented silage ; the Swedish method regulates the biochemical changes

and seeks to produce a fermented silage of good quality from the standpoint of dairy technique. Apparently, however, the controversy has ended satisfactorily, as an agreement has been made between Dr. Virtanen and Valio Co-operative Society in Finland on the one hand, and the National Association of Swedish Farmers on the other, whereby the A.I.V. patent rights have been acquired for Sweden. Presumably, therefore, the A.I.V. method will supersede the molasses method.

In Denmark, ensiling grass has not hitherto been widely practised, it being regarded as a risky method of preserving forage, very often involving heavy loss in the destruction of valuable quantities of food. Consequently the claims made for Virtanen's method are being studied with much interest there. In Denmark, too, priority claims are not lacking. Mr. N. T. Pederson, a Danish State Agricultural expert, writes that he had made ensilage with hydrochloric acid some seven or eight years before Virtanen. The method was as follows: To the fresh green material (kohlrabi leaves) 6 per cent. of a 2N or 3N solution of hydrochloric acid was added. Subsequently, an addition of molasses was made to ensure a rapid formation of lactic acid. The principle here is apparently similar to that involved in the Swedish method noted above.

A close study of the A.I.V. method has been made in Germany. To German science, according to Münzberg, the Finnish method offers but little that is new. In Germany, Fingerling has been working since 1925 on the question of conserving green food with the aid of acids and his applications for patents received early recognition. The Fingerling method is also characterised by conservation through the addition of hydrochloric acid in order to keep the hydrogen-ion concentration below pH 4. Early in 1926 Fingerling reported the results of his experiments to the German Agricultural Society and gave a preliminary account of a test made by Gorlach and Richardson, the outcome of which was that it would be premature to make known the details of the method before further investigation. Trials of the same nature by Wöhlbler are reported to have yielded very good results, showing that by the use of hydrochloric acid, beans, clover-grass, clover, vetches and other leguminous crops could be advantageously ensiled without any loss of nutritive value whatever, provided the pH index 4 was not exceeded.

At the annual meeting of the German Food Conservation Association, held in Berlin in February, 1932, mention was made of the impetus

which had been given to the silo movement in Germany by the reports of the A.I.V. method reaching Germany from Finland. Methods analogous to the A.I.V. are being practised in many and widely separated districts in Germany and are reported to be giving brilliant results. Silage preserved with hydrochloric acid was readily taken by animals and agreed excellently with them, no trace of the added acid being found in the food.

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